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# AIR AND WATER POLLUTION STUDIES RELATED TO PROPOSED PETROLEUM REFINERY FOR SAND ISLAND, OAHU, TERRITORY OF HAWAII

Andrew H. Rose, Jr., et al

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

December 1955

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Report to

Board of Health

Territory of Hawaii

# Air and Water Pollution Studies Related to Proposed Petroleum Refinery for Sand Island - Oahu Territory of Hawaii

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Public Health Service
Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

December 1955

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# REPORT ON
# AIR AND WATER POLLUTION STUDIES
# RELATED TO PROPOSED PETROLEUM REFINERY
# FOR SAND ISLAND, OAHU, TERRITORY OF HAWAII

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Public Health Service

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

December 1955

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## FINDINGS RELATED TO WATER POLLUTION

1. Ocean current studies by means of floats and bacteriological analyses show that longshore currents flow in both directions along the Honolulu Waterfront, and that 37 days out of the year the general current may be expected from Sand Island toward Waikiki Beach.

2. Disposal of phenolic condensates, spent caustic, and oily sludges at sea via crude tanker ballast promises to remove highly pollutional materials from the normal habitat of tuna bait fish.

3. Design of the master oil-water separator was reported to conform to the latest A.P.I. specifications incorporating the open-channel approach and a vertical slot baffle type inlet to give uniform uni-directional flow. Overall dimensions indicate liberal capacity.

4. Effluent from the waste treatment system should be discharged at sea through an outfall sewer at a depth sufficient to give adequate dispersion and assure protection of all beaches in the area.

## FINDINGS RELATED TO AIR POLLUTION

1. The basic refinery process equipment and air pollution control measures to be employed in the proposed refinery will be the most modern and effective known to the engineering profession. The control measures and operating techniques will be such that the discharge of atmospheric contaminants will approach an irreducible minimum as limited by the present state of technical development.

2. The predominant winds, which would carry offshore the atmospheric pollutants discharged from Sand Island, occur 86 percent of the time on the average.

3. Adverse meteorological conditions, which would be associated with maximum surface concentrations in the Honolulu area of atmospheric pollutants discharged from Sand Island, may occur ten days a year on the average. If similar but somewhat less adverse meteorological conditions are included, relatively high surface concentrations would occur 39 days a year, on the average. Two or more days of this kind may be expected in each of the months September to May inclusive. On a typical day of adverse conditions, relatively high surface concentrations of pollutants discharged from Sand Island would occur in localized areas downwind for distances of several miles during a period of one to three hours in the forenoon.

4. Onshore winds of high speed may be expected to lead to relatively high surface concentrations of those air contaminants discharged from any elevated sources on Sand Island. This effect would be noticeable only up to a few thousand feet from the elevated source. Sufficiently high hourly wind speeds may be expected about 50 times a year.

5. Evidence has been reported by others that threshold limits have been reached in the Honolulu atmosphere in terms of two manifestations of atmospheric pollution: (1) typical pollution haze and (2) damage to certain genera of vegetation.

6. The two manifestations observed, atmospheric pollution haze and damage to vegetation, have been attributed in other areas of the world to the photochemical reaction of hydrocarbon vapors and $NO_2$. In addition a third manifestation, irritation of the mucous membranes, has been attributed to the same photochemical reaction products. The possible development of a similar manifestation in the Honolulu area should be recognized.

7. Using hydrocarbon vapors as an indicator, the 3.25 tons per day computed emissions from the limited area-source represented by the proposed 24,000

barrel per day refinery would constitute a 20 percent increase over the 16 tons per day computed emission from the existing industrial limited area-source. Any future expansion of the proposed refinery would result in a further increase.

8. While location of the refinery as proposed would thus result in increased levels of air pollution under adverse meteorological conditions, no valid prediction of the degree of effect of this added pollution can be made in the present state of knowledge.

## AUTHORITY

This project was initiated by a letter dated September 16, 1955 from Dr. Leo Bernstein, M.D., Acting Executive Officer, Department of Health, Territory of Hawaii directed to Dr. Richard F. Boyd, Regional Medical Director, U.S. Public Health Service, San Francisco, California. A copy of this communication and subsequent pertinent correspondence are made a part of this report as Appendix A.

## OBJECTIVES

Conforming with a request from the Department of Health, Territory of Hawaii, studies were conducted October 19 to October 27, 1955 of the water and air pollution potential of a petroleum refinery proposed for Sand Island, which is located at the entrance to Honolulu Harbor, with the objective of estimating the impact this industrial development would have on the local environment.

## SCOPE OF STUDIES

The scope of this work included investigations in the following areas:

1. Protection of Beaches
2. Effect on Fishing Industry
3. Control and Treatment of Liquid Wastes
4. Atmospheric Pollution Thresholds
5. Existing Sources of Atmospheric Pollution
6. Refinery Discharges of Atmospheric Pollution
7. Effects of Refinery Atmospheric Pollution Discharges

## SOURCES OF INFORMATION

Representatives of the Territorial Department of Health were most cooperative in arranging meetings and securing data pertinent to this study. During the course of this field investigation, meetings were held with several officials and interested groups. The following list records the principal

contacts:

Governor Samuel W. King

Dr. Richard K. C. Lee, President, Territorial Board of Health

Dr. Leo Bernstein, Acting Executive Officer, Territorial Board of Health

Mr. B. J. McMorrow, Director, Division of Sanitation, Territorial Board of Health

Miss Marguerite K. Ashford, Commissioner of Public Lands

Mr. Frank Eustace, Member Land Board

Lt. Col. Shelley, Area Engineer, Corps of Engineers, U. S. Army

Dr. Vernon E. Brock, Director, Division of Fish and Game, Board of Agriculture and Forestry

Mr. B. J. Rush, Manager and Chief Engineer, Board of Harbor Commissioners

Mr. Dan A. Davis, U. S. Geological Survey

Drs. J. H. Beaumont, H. Kamemoto, and Kobe Shoji, Experimental Station, University of Hawaii

Commander William I. Kanakanui, Secretary, Tuna Boat Owners Association

Mr. Otto N. Miller, Vice President in Charge of Manufacturing Operations, Standard Oil Company of California

Mr. Fred Powell, General Manager, Manufacturing Department, Standard Oil Company of California

Mr. E. J. McClanahan, Vice President and Director, Western Operating Division, Standard Oil Company of California

Dr. Paul L. Magill, Stanford Research Institute

Mr. H. Dean Parry, Chief Airport Meteorologist, United States Weather Bureau, Airport Station, Honolulu, Hawaii

Board of Health, Territory of Hawaii

Honolulu City Planning Commission

Public Health Committee, Honolulu Chamber of Commerce

## REFINERY SITES INVESTIGATED

Standard Oil Company of California has considered various sites on the islands of Hawaii, Maui, Kauai, and Oahu. Six sites were investigated on Oahu alone. These were Kaneohe, Barbers' Point, Iwa, Pearl City, Pearl Harbor and Sand Island (See Fig. 1). Sand Island has been favored by Standard Oil Company of California because of:

1. The deep-water terminal which is suitable for super tankers.
2. Proximity to military and naval establishments, and the most densely populated area of the islands.

## PROPOSED HAWAIIAN REFINERY

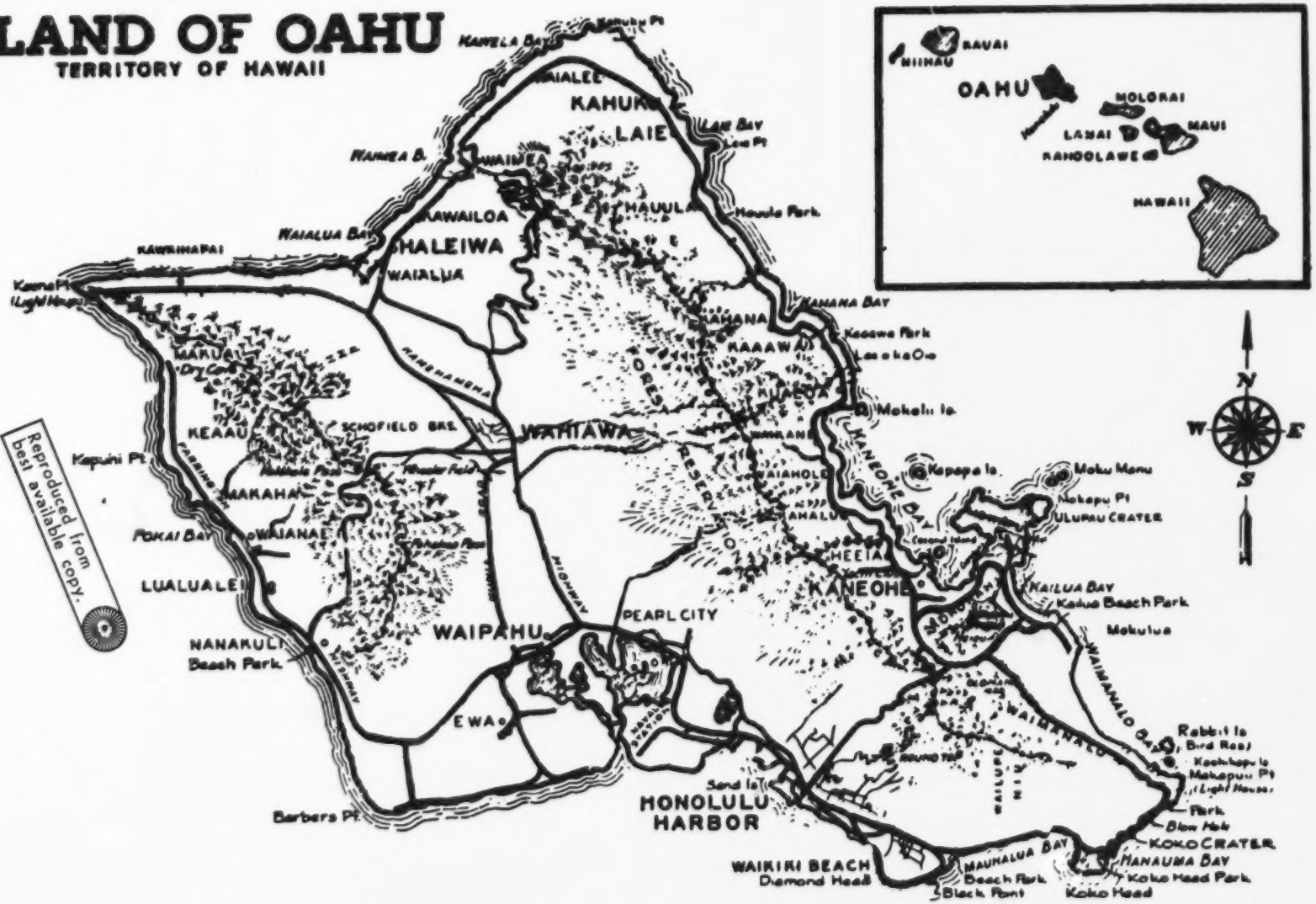
Mr. R. G. Follis, Chairman of the Board, Standard Oil Company of California, announced on November 29, 1954 at a meeting held at the Royal Hawaiian Hotel, the plans of his company to construct an oil refinery in the Hawaiian Islands. This proposal called for a 24,000 barrel per day (BPD) oil refinery on a 200 acre tract of land along the south edge of Sand Island which is located at the entrance to Honolulu Bay. A mixed base, medium sulfur crude from the Far East is available by tankers. Proposed finished products included: civilian and military grades of motor gasoline, aviation gasoline, jet fuels, 50 cetane Diesel, regular Diesel, furnace oil, Navy special fuel, regular fuel oil and liquefied petroleum gas. Future plans are not definite but with normal expansion, this refinery could be expected to process 40,000 barrels per day by 1965.

The basic refinery process equipment to be employed in the proposed refinery is of the most modern design. This includes seven unit processes as described below:

FIGURE 1

# ISLAND OF OAHU

TERRITORY OF HAWAII


KAHUKU
LAIE
HAUULA
KAWAILOA
HALEIWA
WAIALUA
KAWAILOA
KAHANA BAY
KAAAWA
KUALOA
WAHIAWA
SCHOFIELD BAR
KEAAU
MAKAHA
WAIANAE
LUALUALEI
NANAKULI Beach Park
WAIPAHU
PEARL CITY
EWA
Barbers Pt
HONOLULU HARBOR
Sand Is
WAIKIKI BEACH
Diamond Head
Black Point
Koko Head
KANEOHE
HEEIA
WAIAHOLE
Mokoli'i Is
Kapapa Is
Moku Manu
Mokapu Pt
ULUPAU CRATER
KAILUA BAY
Kailua Beach Park
Mokulua
WAIMANALO BAY
Rabbit Is
Bird Rock
Makapuu Pt
Light House
Park
Blow Hole
KOKO CRATER
MANAUMA BAY
Koko Head Park
MAUHALUA BAY
Beach Park
KAWAILOA
Kaena Pt
Light House
KAWAILOA
Kaena Park
Laie Bay
Laie Pt
Hauula Park
Waialua Bay
Kawailoa
Kahana Bay
Kaaawa Park
Kaneohe Bay
Kapapa Is
Moku Manu
Mokapu Pt
Ulupau Crater
Kailua Bay
Kailua Beach Park
Mokulua
Waimanalo Bay
Rabbit Is
Bird Rock
Makapuu Pt
Light House
Park
Blow Hole
Koko Crater
Manauma Bay
Koko Head Park
Mauhalua Bay
Beach Park
Black Point
Waikiki Beach
Diamond Head
Honolulu Harbor
Sand Is
Barbers Pt
Ewa
Waipahu
Pearl City
Nanakuli Beach Park
Lualualei
Waianae
Makaha
Keaau
Schofield Bar
Wahiawa
Waialua
Haleiwa
Kahuku
Laie
Kawailoa
Hauula
Kahana
Kaaawa
Kualoa
Kaneohe
Heeia
Waiahole
Kapuni Pt
Pokai Bay
Kaena Pt
Light House
Waialua Bay
Kawailoa
Kawailoa
Kahuku
Laie
Laie Bay
Laie Pt
Hauula
Hauula Park
Kahana Bay
Kaaawa
Kualoa
Kaneohe Bay
Mokoli'i Is
Kapapa Is
Moku Manu
Mokapu Pt
Ulupau Crater
Kailua Bay
Kailua Beach Park
Mokulua
Waimanalo Bay
Rabbit Is
Bird Rock
Makapuu Pt
Light House
Park
Blow Hole
Koko Crater
Manauma Bay
Koko Head Park
Mauhalua Bay
Beach Park
Black Point
Waikiki Beach
Diamond Head
Honolulu Harbor
Sand Is
Barbers Pt
Ewa
Waipahu
Pearl City
Nanakuli Beach Park
Lualualei
Waianae
Pokai Bay
Makaha
Keaau
Schofield Bar
Wahiawa
Waialua
Haleiwa
Kahuku
Laie
Kawailoa
Hauula
Kahana
Kaaawa
Kualoa
Kaneohe
Heeia
Waiahole
Kapuni Pt
Kaena Pt
Light House
Kawailoa
Waialua Bay
Kawailoa
Kahuku
Laie
Laie Bay
Laie Pt
Hauula
Hauula Park
Kahana Bay
Kaaawa Park
Kaneohe Bay
Mokoli'i Is
Kapapa Is
Moku Manu
Mokapu Pt
Ulupau Crater
Kailua Bay
Kailua Beach Park
Mokulua
Waimanalo Bay
Rabbit Is
Bird Rock
Makapuu Pt
Light House
Park
Blow Hole
Koko Crater
Manauma Bay
Koko Head Park
Mauhalua Bay
Beach Park
Black Point
Waikiki Beach
Diamond Head
Honolulu Harbor
Sand Is
Barbers Pt
Ewa
Waipahu
Pearl City
Nanakuli Beach Park
Lualualei
Waianae
Pokai Bay
Makaha
Keaau
Schofield Bar
Wahiawa
Waialua
Haleiwa
Kahuku
Laie
Kawailoa
Hauula
Kahana
Kaaawa
Kualoa
Kaneohe
Heeia
Waiahole
Kapuni Pt
Kaena Pt
Light House

1. Crude Distillation

A two stage crude distillation unit of 24,000 BPD capacity in which crude oil is separated into elementary products for further processing. The equipment will include two fractionating columns, one atmospheric and one vacuum, together with the necessary fired heaters, rectifier columns, side cut stripper columns and auxiliary equipment.

2. Fluid Catalytic Cracker

An 11,500 BPD fluid catalytic cracking unit to break down long chain high-molecular weight hydrocarbons for processing into motor and aviation gasoline components. The principal equipment will consist of a fired heater, a reactor, and regenerator and a products fractionation section.

3. Catalytic Alkylation

A catalytic alkylation unit of 2500 BPD capacity to effect a catalytic reforming of iso-paraffins and olefins for the production of aviation alkylate blend used in aviation gasoline. The principal equipment will include a reactor, a product fractionation section and auxiliary equipment.

4. Catalytic Polymerization

A catalytic polymerization unit of 450 BPD capacity for the catalytic uniting of light hydrocarbon fractions, resulting from the catalytic cracking operations, for the production of polymer gasoline and alkylation feed stock. The principal equipment will include mercaptan removal section, reactors, and a product fractionation section.

5. Perco Sweetener

A 4000 BPD capacity copper chloride sweetener unit for quality improvement of straight run gasoline by the conversion of the mercaptan content of the product into disulfide. The equipment is basically a reactor and auxiliary equipment.

6. Caustic Treater

A caustic treating unit of 6000 BPD capacity for the quality improvement of catalytically cracked gasolines for the removal of mercaptans from the product. The principal equipment will include a treater and settling section.

7. Sulfur Removal Unit

Hydrogen sulfide and sulfur conversion unit to remove the hydrogen sulfide from the refinery fuel gases and the conversion of hydrogen sulfide into elemental sulfur.

The control measures to be employed in the proposed refinery are the most modern and effective known to the engineering profession. Methods proposed for handling liquid wastes are:

1. Phenolic condensates, spent caustic, and oily sludges are to be conveyed from the site as tanker ballast.

2. Oily water is passed through an American Petroleum Institute (A.P.I.) oil-water separator of latest design.

3. A storm water retention basin of 3,000,000 gallons capacity has been provided to reduce storm flow through the A.P.I. separator.

4. Effluent from the A.P.I. separator will be treated by chemical flocculation for further oil removal.

The air pollution control measures which will be included in the design of the refinery and which are planned for in the operating techniques, to reduce the discharge of atmospheric pollutants, are as follows:

1. American Petroleum Institute type separators which contain light distillates will be totally enclosed to prevent air pollution.

2. Gasoline and other light products (greater than .1 PSI absolute vapor pressure) will be stored in floating roof tanks to prevent evaporation.

3. All gasoline and light hydrocarbon fractionation pumps will be equipped with mechanical seals to prevent leakage.

4. The discharge of oxides of sulfur to the atmosphere will be essentially eliminated by the recovery of hydrogen sulfide from the major portion of the refinery fuel gas.

5. Flue gas from the fluid catalytic cracking plant which normally contains hydrocarbon vapors and carbon monoxide will be completely incinerated so that it will contain only the usual products of combustion.

6. Essentially all dust will be removed from the flue gas of the catalytic cracking plant by electrostatic precipitators.

7. A closed system will be provided so that hydrocarbon vapors which are released through safety valves will be contained for recompression and return to the refinery fuel gas system. In the event of an unusual emergency, the excess gas will be incinerated in smokeless flares.

8. Waste gaseous effluents from the caustic regenerator, the crude unit water stripper, the catalytic cracker water stripper and the vacuum jets from the crude unit will be incinerated to prevent the discharge of mercaptans and hydrogen sulfides to the atmosphere.

9. Improved operational techniques and the use of specialized equipment will reduce the discharge to the atmosphere of gaseous pollutants below that anticipated from present refining operations.

## WATER POLLUTION ASPECTS

Protection of the beaches and the fishing industry are of paramount importance. This involves ocean currents along the Honolulu waterfront, dispersion of treated wastes, and all phases of waste control, handling, and treatment.

### Bacteriological Studies

The City of Honolulu has a population of 260,000 of which approximately 60 per cent is presently connected to the sanitary sewer system. Sewage is discharged through three major outfalls shown on Fig. 2. A new pumping station, nearing completion, will permit abandonment of the Ala Moana and the Ward Avenue outfalls with discharge of all city sewage through the Sand Island outfall. Information on the present outfalls and sewage flows are tabulated below:

| Name of Outfall | Diameter in. | Discharge Depth Feet | Discharge Present m.g.d. | Discharge Future m.g.d. |
|---|---|---|---|---|
| Ward Avenue | 48 | 60 | 21 | 0 |
| Ala Moana | 24 | 21 | 13 | 0 |
| Sand Island | 78 | 42.5 | 4 | 61 |

Coliform determinations are recognized as sensitive indicators of sewage movements in receiving waters and therefore are useful in showing ocean currents. Bacteriological studies have been made along the Honolulu Waterfront from Diamond Head to Ahua Point. The report of Metcalf and Eddy on Sewerage and Sewage dis-

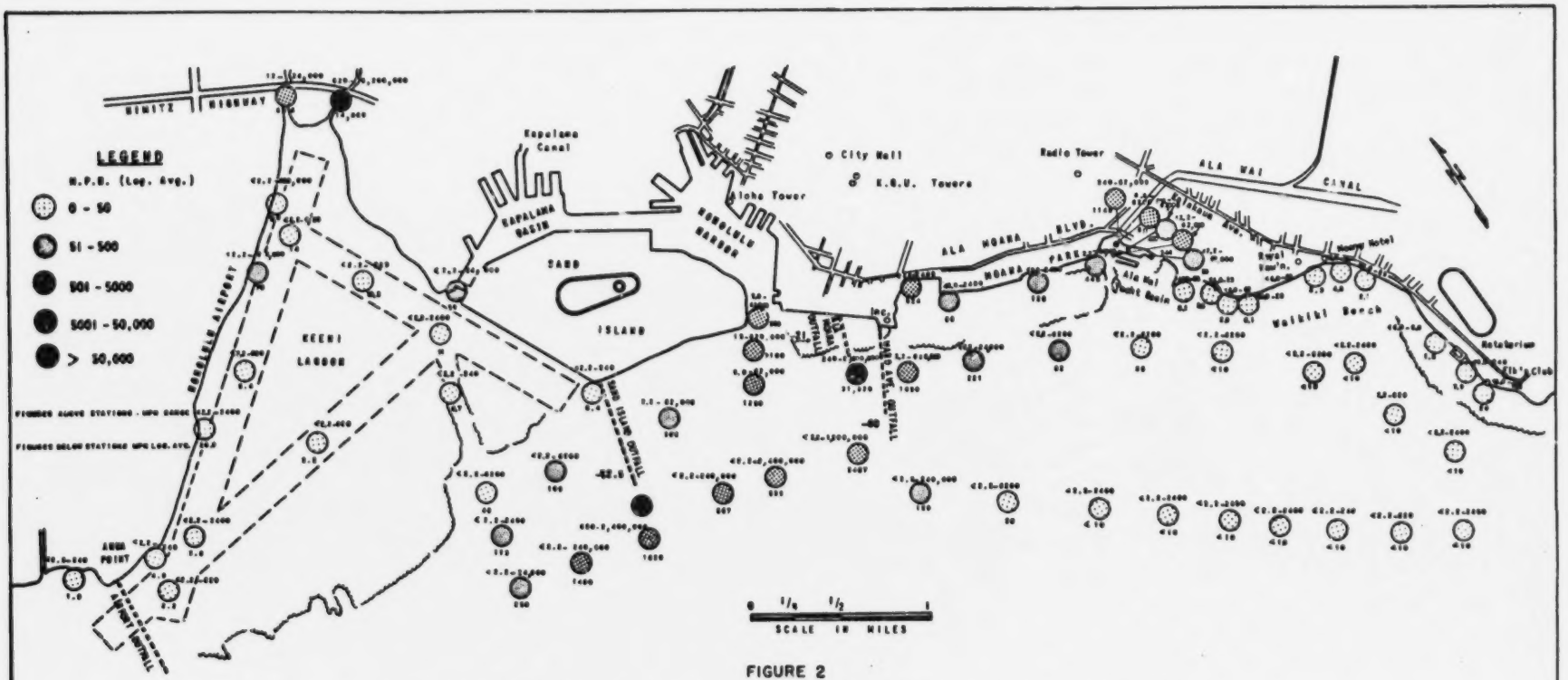



FIGURE 2

BACTERIOLOGICAL STUDIES, 1953, M.P.N. RANGE AND LOG AVERAGE

CITY AND COUNTY OF HONOLULU

TERRITORY OF HAWAII

posal for Honolulu contains coliform data for this area.[1] More recent studies have been made on a weekly basis during 1952 and 1953 by the Department of Public Works, City and County of Honolulu.

The following excerpts are taken from the Metcalf and Eddy report, Volume I, Page 201.

"Standards for the safety of waters for bathing at ocean beaches need not be as high as those for drinking water supplies. Several bacterial standards of safety have been proposed from time to time, based on the number of members of the coli-aerogenes group found in such waters. These standards vary greatly, but generally fall between 50 and 1000 per 100 ml. In some cases, a standard as high as 3000 per 100 ml. has been proposed."

"The analysis of the bacterial counts off Waikiki when the wind was blowing in that direction from the outlets indicates that the bathing and surfing waters there are at such times more highly polluted than the lower of these standards and at times their pollution equals or exceeds the limit of 1000, while a few counts as high as 10,000 per 100 ml. have been obtained."

"Likewise, the pollution of the waters from east of Fort De Russy to the southwest corner of Sand Island, at times even during periods of trade winds, equaled or exceeded the standard of 1000 per 100 ml."

Summary coliform data for the 1953 survey by the City and County of Honolulu are recorded in Fig. 2. These data show highest bacterial counts in the vicinity of the sewer outfalls as would be expected. However, the maximum bacterial counts in the Waikiki area cannot be accounted for by discharge from the Ala Wai Canal. The data strongly suggest that the sewage revealed by these coliform results must have originated in the discharge from the three major city sewer outfalls. These results support conclusions from the float

studies pertaining to ocean currents in the Sand Island - Waikiki area, which are discussed in the next section.

The bacteriological results indicating sewage dispersion along the Honolulu Waterfront are further supported by similar bacteriological studies recently conducted along the southern California Coast as reported by Nusbaum, Miller, and Reinhardt.[2] The conclusions from the California studies follow:

"A nearshore system of water circulation exists in the ocean which is important to the distribution of pollution which may be discharged near the shore or at some point where it may reach the shore. Such pollution may travel relatively long distance with slight dissipation, thus affecting beneficial uses of the waters over a significant area."

"Along the Southern California Coast the longshore currents are frequently found to flow in either direction with only slight dominance of one direction over the other. Data obtained in a series of bacteriological studies shows that the longshore current pattern should be determined before wastes are disposed of in inshore waters."

Ocean Currents

Ocean current studies using both sub-surface and surface floats were conducted in the vicinity of the Sand Island outfall sewer two to three times a week from September 1950 to May 1951. This work was done by the Department of Public Works, City and County of Honolulu, Division of Sewers, and prior to placing the sewer in service. The purpose of these studies was to estimate the extent to which pollution of the surrounding waters might occur when 50 m.g.d. of sewage were discharged 3500 feet from the Sand Island shore at a depth of 42.5 feet. Based on the method proposed by Rawn and Palmer the radius of the sewage field for the 50 m.g.d. flow was 1300 feet, and the average

thickness was slightly less than 4 feet.[3] These computations were based on the assumption that no ocean current exists.

Data collected during this survey indicated that the general current flow will be westward (Ewa) for 270 days, eastward (Diamond Head) for 37 days, south (seaware) for 44 days, and north (straight inshore) for 14 days out of the year. On February 20, 1951, a stormy "Kona" day, one float released at the mouth of the outfall sewer reached shore in one hour and fifteen minutes. The Sand Island shore was the only area which the float tests indicated as being susceptible to serious pollution. Although not confirmed by float tests, it was concluded that when the discharge from the 3500 foot outfall greatly exceeded 50 m.g.d., sewage pollution might extend to the beaches west of Honolulu Harbor and even to Waikiki. This conclusion is supported by the results of bacteriological studies discussed in the preceding section.

## BEACH PROTECTION

The magnitude and potential of the tourist industry make it mandatory that the Hawaiian beaches be protected from oil pollution. The information given in sections headed "Bacteriological Studies" and "Ocean Currents" provides incontrovertible evidence that longshore currents flow in both directions along the Honolulu Waterfront. These conditions will require a high degree of treatment for refinery effluents. The location and depth of the refinery discharge are likewise of major importance.

## EFFECT ON FISHING INDUSTRY

Concern has been expressed by Hawaiian fishing interests regarding possible damage to tuna bait fish from liquid wastes discharged from an oil refinery located on Sand Island. This threat was discussed at some length with Dr. Vernon

E. Brock, Director, Division of Fish and Game, Board of Agriculture and Forestry, and with Commander William I. Kanakanui, Secretary, Tuna Boat Owners Association. The commercial value of the Territorial fishing industry is indicated in Table 1, furnished by Dr. Brock.

Tuna bait fish seek fresh, calm waters and are found extensively in Pearl and Honolulu Harbors. It was estimated that 80 per cent of the bait catch in the Honolulu area was from Pearl Harbor and 15 per cent from Honolulu Harbor. Based on the fisherman's time consumed in collecting bait fish, it has been determined that bait fish are worth $4.00 per pound. This means that the annual bait fish catch in the Honolulu area is worth $200,000.

## CONTROL AND TREATMENT OF LIQUID WASTES

### Refinery Sewer System

Liquid wastes have been segregated into four collection systems. These are:

1. Storage of concentrated wastes for transport to sea by barge.
2. Process sewer which receives oily water, and storm water from process and tankage areas.
3. Separate storm discharge.
4. Sanitary sewer.

Computations for a 10 year storm cause design flow through the process sewer system to range from 250 to 25,000 G.P.M. Storm water discharge is significant because of requirements imposed on the effluent treating system. There is no reference to an outfall sewer.

### Phenol and Spent Caustic

It is planned to dispose of phenolic condensates and spent caustic at sea via barge or crude tanker ballast. This practice will remove a high per-

# TABLE I

## CATCHES OF BAIT AND FISHES FOR AREA (400-401-420-421)**
## LESS AKU AND AHI BOAT CATCHES
## COMPARED TO TERRITORIAL CATCHES

| | AREA 400 - 401 - 420 - 421 LESS AKU AND AHI BOAT CATCHES | | TERRITORIAL CATCHES | | BAIT CATCH FOR ALA WAI, KEWALO, HON. HARBOR, KALIHI PEARL HARBOR | TERRITORIAL BAIT CATCH |
|---|---|---|---|---|---|---|
| | LBS. | VALUE | LBS. | VALUE | BUC. * | BUC. * |
| 1950 | 125,874 | $ 64,150.78 | 16,059,446 | $ 3,503,747.89 | 4,519 | 20,594 |
| 1951 | 163,112 | 82,397.13 | 19,292,736 | 3,963,427.52 | 7,797 | 36,452 |
| 1952 | 169,529 | 87,694.07 | 13,854,715 | 3,408,893.83 | 9,535 | 28,498 |
| 1953 | 126,708 | 71,554.52 | 18,798,536 | 3,758,217.29 | 12,656 | 36,906 |
| 1954 | 134,656 | 66,754.92 | 20,523,375 | 3,653,359.23 | 9,683 | 43,737 |
| TOTAL | 719,879 | $ 372,551.42 | 88,528,908 | $ 18,287,372.76 | 44,190 | 166,187 |

8-01

** SOUTH OF HONOLULU AND PEARL HARBOR

* BUCKET OF BAIT FISH VARIES BETWEEN 5 AND 7.5 LB. AND AVERAGES 6 LB.

centage of phenol and mercaptan bearing wastes from the refinery site. These are highly objectionable constituents in petroleum refinery effluents. Oily sludges are likewise to be barged to sea. The dumping ground has not been specified. In this connection, a recent Corps of Engineers publication specifies that oil and similar insoluble floating matter, disposed of at sea, should be discharged beyond 50 miles from shore.[4] If for some reason barging of concentrated phenolic wastes to sea does not prove feasible, methods are available for satisfactorily treating such wastes by biological oxidation. Oily sludges can be handled by centrifugation and incineration.

Effluent Treating System

The proposed effluent treating system is shown schematically in Fig. 3. This system is comprised of an A.P.I. oil-water separator, storm water retention basin, chemical flocculation, sludge dewatering beds, and acid-caustic neutralization. The computed normal discharge rate is 250 G.P.M. with a maximum of 7,000 G.P.M. from storm runoff. The plan indicates that the treated wastes will contain less than 5 parts per million oil which represents better than 99.5 percent removal. This efficiency exceeds that reported for like treatment in the United States. It is not generally practicable to remove the last visible traces of oil from the effluent of a petroleum refinery.

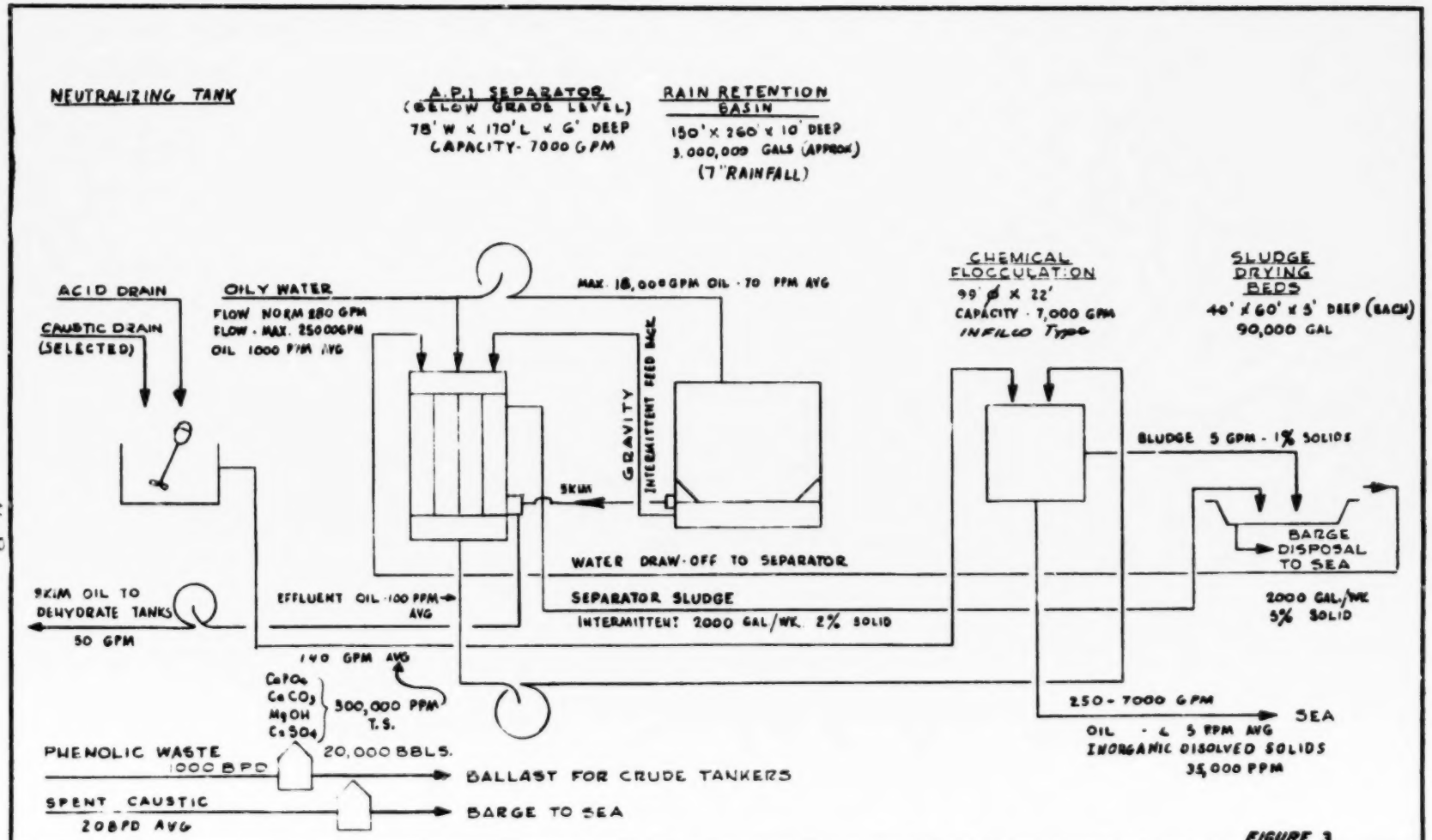



FIGURE 3

| REVISIONS | | | | | | Eng. Dept. App. | Operating Dept App. | STANDARD OIL CO. of CALIFORNIA HAWAIIAN REFINERY | SCALE NONE DATE |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | | | 6 | | | | | DR. R.H CH. |
| | 2 | | | 7 | | | | | JOB ENG. |
| | 3 | | | 8 | | | | EFFLUENT TREATING | DRAWING NO. SK OL-1-51 |
| | 4 | | | 9 | | | | | |
| | 5 | | | 10 | | | | | |

## AIR POLLUTION ASPECTS

The objective of the atmospheric pollution phase of this study is an evaluation of the possible effect on the atmosphere of the City of Honolulu which may result from the operation of a 24,000-barrel-per-day modern fluid catalytic cracking refinery. In order to accomplish this objective, two factors must be investigated, first the extent and causes of the present atmospheric pollution level, and second the potential impact on the pollution level which may result from the refinery operation.

This study is limited by certain considerations. Process design for the proposed refinery is tentative in that only process flow and major process units are fixed; interflow of components between process units and their elements has not been finalized. Data covering the operation of and atmospheric contaminant discharge from existing industrial operations are relatively meager. Data on the concentrations of specific contaminants in the Honolulu atmosphere are not available. Only published climatological data were available. The present report therefore gives the quantity of specific atmospheric contaminants from both existing sources and the proposed refinery as determined from the best available data.

### INDICATIONS OF THE EXTENT OF PRESENT ATMOSPHERIC POLLUTION

Air pollution is a direct consequence of man's activities. Factories, motor vehicles, and rubbish burners, to enumerate three categories, contribute pollutants in the gaseous, liquid, or solid state. Many of these pollutants react in the atmosphere and so acquire chemical or physical characteristics which the original pollutants did not have at the point of discharge. For the purpose of this study, atmospheric pollution may be considered as an atmospheric condition defined in terms of its identifiable effects: (1) irrita-

tion of the mucous membranes, (2) reduced visibility, (3) oxidant formation and (4) plant damage. This definition, while arbitrary, does have the advantage that it distinguishes between gross air pollution and the specific original pollutants from which the objectionable effects eventually develop. Effects (2) and (4) have been reported in the Honolulu area.

Atmospheric Pollution Haze

Precise data relative to reduction of visibility by typical atmospheric pollution haze are not available. However, an evaluation of this phenomenon by Wendall A. Mordy[5] indicates that a pollution haze exists in the Honolulu area within the surface-based inversion in varying degrees of intensity during certain periods of winter months when the meteorological conditions are favorable to slow dispersion of air pollution. When these meteorological conditions occur, they usually persist through the early morning hours from midnight to a few hours before noon. The occurrence of haze is generally limited to the period following sunrise. Such an atmospheric condition was observed over the period October 21-24, 1955, during the course of this investigation.

The typical atmospheric pollution haze found in other areas has been attributed to the photo-chemical reaction of the same gaseous contaminants as are found in the Honolulu atmosphere, specifically hydrocarbon vapors and $NO_2$. While quantitative data relative to the occurrence of this reaction in the Honolulu area are not available, the probable existence of this phenomenon should be considered in evaluating the causes of the pollution haze.

Orchid Damage

Evidence of damage to certain genera of orchids was first indicated in

a preliminary investigation performed by Dr. J. H. Beaumont[6] and associates at the University of Hawaii. This investigator concluded that observed damage to orchid flowers in the Honolulu area was attributable to atmospheric contaminants which are normally carried out to sea but which under adverse meteorological conditions move over the land mass. Moreover, orchid damage was experimentally produced by passing an air sample over an enclosed plant.

Additional evidence relative to orchid injury is available from the study by Dr. John T. Middleton of the Agricultural Air Pollution Advisory Research Committee, State of California, included as Appendix B of the present report. This study reports two types of flower injury to orchids in the Honolulu area. The first type, called "dry sepal," is attributable to a gaseous effluent attack which causes the apical portion of the sepal to become dry, sunken, and somewhat brittle. The toxicant responsible for this type of injury may be ethylene or associated short-chain unsaturated hydrocarbons. The second type of damage, in which the petals of the flower are the principal portion injured, is apparently attributable to particulate deposits. Damage typical of dry sepal injuries has been reported since the mid-1930's and has been increasing yearly both as to the geographical area affected and the extent of injury to the orchid. Dr. Middleton further establishes that the area of occurrence of maximum injury to orchids, attributable to gas-phase pollutants, is in the Kalihi Valley immediately adjacent to the existing industrial area.

Significant observations reported by Beaumont and Middleton may be summarized as follows: First, not only has the intensity of plant injury increased with industrial growth, but the geographical area of maximum damage is adjacent to the industrial area. Second, damage is attributable to specific hydrocarbon vapors resulting from atmospheric pollution.

## EXISTING SOURCES OF ATMOSPHERIC POLLUTION

In order to evaluate the impact on the atmosphere which may result from the proposed refinery operation, the order of magnitude of the pollutant discharges from existing sources must be established. Since any impact of the refinery activity on the atmosphere in the Honolulu area will be primarily gaseous, its effect must be evaluated in terms of all gaseous contaminants presently found in that atmosphere rather than in terms of total contaminants (gaseous, liquid and solid particulates). Existing pollution sources were therefore considered only in terms of their gaseous contaminant discharges, namely hydrocarbon vapors, $NO_2$, and $SO_2$. Further, all sources were catalogued according to the method of contaminant generation, that is, industrial losses due to petroleum marketing, industrial losses due to combustion and automobile exhaust losses, Table II.

### Losses Due to Petroleum Marketing

The tabulation indicates that only hydrocarbon vapors are discharged in marketing operations. Such discharges result from transfer and automotive evaporation losses and from storage losses. Transfer and evaporation losses were determined by applying a proportionality constant to the results of loss measurements made on similar installations operating under conditions approximating those of the Honolulu installations. Storage losses were calculated using the American Petroleum Institute correlation method based on a detailed inventory of the type and size of tank, the material handled, and the volume throughput.

### Losses Due to Combustion and Automotive Exhausts

$NO_2$ and $SO_2$ are the principal contaminant discharges resulting from in-

# TABLE II

## SUMMARY OF GASEOUS CONTAMINANT LOSSES
## EXISTING SOURCES – HONOLULU AREA

| SOURCE OF LOSS | EMISSIONS – TONS / DAY | | | | | |
|---|---|---|---|---|---|---|
| | HYDRO CARBON | TOTAL | NITROGEN DIOXIDE | TOTAL | SULFUR DIOXIDE | TOTAL |
| **PETROLEUM PRODUCTS MARKETING** | | 14.00 | | — | | — |
| FILLING - AUTOMOBILE TANK | 0.75 | | | | | |
| FILLING - SERVICE STATION TANK | 0.90 | | | | | |
| EVAPORATION - AUTOMOBILE TANK & CARBURETOR | 5.25 | | | | | |
| TRANSFER - TRUCK | 0.55 | | | | | |
| TRANSFER - TANKERS | 0.15 | | | | | |
| STORAGE - GASOLINE, ETC. | 5.45 | | | | | |
| STORAGE - DISTILLATES, ETC. | 0.95 | | | | | |
| **INDUSTRIAL LOSSES** | | — | | 15.40 | | 16.50 |
| FUEL OIL COMBUSTION | — | | 14.85 | | 16.50 | |
| GAS COMBUSTION | — | | .55 | | — | |
| **AUTOMOTIVE EXHAUST.** | | 28.30 | | 5.65 | | 1.25 |
| TOTAL | | 42.30 | | 21.05 | | 17.75 |

15-18

dustrial combustion processes. $NO_2$ results from the fixation of atmospheric nitrogen supplied with the combustion air. $SO_2$ is formed from the sulfur content of the fuel and is therefore directly determined by the percentage of sulfur in the fuel burned. Investigations by others[7] indicate specific quantities of $NO_2$ produced from the combustion of fuel oil and manufactured gas. These relationships were used to establish $NO_2$ discharge values. $SO_2$ emission determinations were based on an estimate of percentages of sulfur contained in the fuel.

A review of available literature pertaining to gaseous pollutants from automotive exhausts[7,8,9] indicates the quantities of hydrocarbon vapors, $NO_2$, and $SO_2$ discharged per unit of gasoline consumed. Since the present study required only order of magnitude of contaminant discharges, averages, weighted according to the relative duration of cruising, idling, deceleration, and acceleration operations, were used in the determinations, tabulated in Table II.

Effects

Total gaseous contaminants discharged into the Honolulu atmosphere from existing sources, as shown in Table II, amount to approximately 42 tons per day of hydrocarbon vapors, 21 tons per day of $NO_2$, and 18 tons per day of $SO_2$. As already mentioned, two manifestations of atmospheric pollution have been reported to occur in the Honolulu area: (1) a characteristic atmospheric pollution haze, and (2) gas phase injury to certain genera of vegetation. The photochemical reactions of hydrocarbon vapors and $NO_2$ are known to produce these manifestations in other areas. Hence, the probable existence of similar reactions in the Honolulu atmosphere should be recognized.

It is generally conceded that atmospheric pollution effects increase as a function of increase in concentration of pollutants in the atmosphere. Lim-

ited areas with emission of pollution in high concentrations must be separately considered in evaluating the effect of all existing sources. For this reason the industrial area, Fig. 4, is taken as a limited area-source of contaminants in high concentrations. Contaminants from automotive sources, however, are discharged throughout the Honolulu area and therefore constitute an extended area-source. Including a portion of this automotive source contamination prorated to the limited industrial area on the basis of vehicle miles, a function of gasoline consumed, the total hydrocarbon discharge from this limited, industrial area-source is approximately 16 tons per day.

## REFINERY DISCHARGES OF ATMOSPHERIC POLLUTION

To determine the effect on the atmosphere of Honolulu which may be exerted by the refinery, three elements of the refinery operation and design must be considered: (1) the basic process equipment to be employed in the refinery, (2) the degree to which the proposed design will succeed in limiting to an irreducible minimum the discharge of atmospheric contaminants, and (3) the computed discharge of contaminants to the atmosphere from the refinery losses based on an evaluation of the first two considerations.

The tabulation of refinery contaminants, Table III, indicates the magnitude of gaseous contaminant losses, specifically 3.25 tons per day of hydrocarbon vapors, 1.35 tons per day of $NO_2$, and 3.25 tons per day of $SO_2$. These losses fall into two classifications; (1) storage losses resulting from the evaporation of hydrocarbons and (2) process losses consisting of hydrocarbon vapors due to leakage, spillage, etc., and $NO_2$ and $SO_2$ losses resulting from combustion operations.

Losses resulting from storage were calculated using the American Petroleum Institute correlation method. Process hydrocarbon losses were deter-

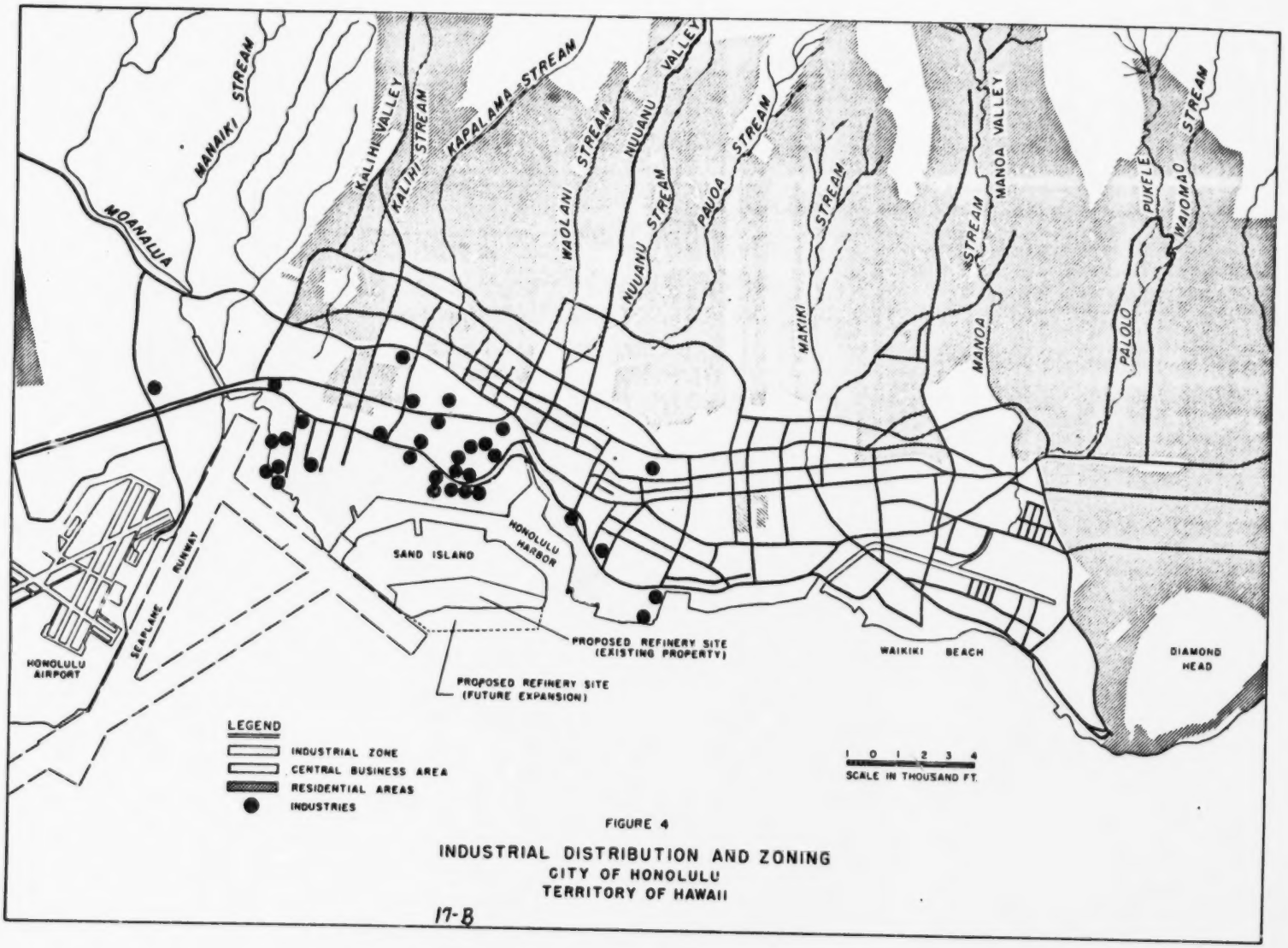



FIGURE 4

INDUSTRIAL DISTRIBUTION AND ZONING
CITY OF HONOLULU
TERRITORY OF HAWAII

# TABLE III

## SUMMARY OF GASEOUS CONTAMINANT LOSSES
## PROPOSED REFINERY

| SOURCE OF LOSS | EMISSIONS - TONS / DAY | | | | | |
|---|---|---|---|---|---|---|
| | HYDRO CARBON | TOTAL | NITROGEN DIOXIDE | TOTAL | SULFUR DIOXIDE* | TOTAL |
| **STORAGE** | | 1.85 | | — | | — |
| GASOLINE & BLENDING CUTS | 1.00 | | — | | — | |
| CRUDE | 0.65 | | — | | — | |
| HEAVY DISTILLATES | 0.20 | | — | | — | |
| **PROCESS** | | 1.40 | | 1.35 | | 3.35 |
| SEPARATORS & SEWERS | 0.20 | | — | | — | |
| BLOWDOWN, SHUTDOWN & RELIEF | 0.05 | | — | | — | |
| PUMP GLAND | 0.30 | | — | | — | |
| BLIND CHANGING | 0.10 | | — | | — | |
| HEATERS & BOILERS | — | | 1.20 | | 1.50 | |
| CATALYTIC CRACKER & CO BOILER | — | | 0.15 | | 1.85 | |
| MISCELLANEOUS | 0.75 | | — | | — | |
| TOTAL | | 3.25 | | 1.35 | | 3.35 |

*ASSUMED OIL PROCESSED TO BE COMPOSED OF 50% *ARABIAN* & 50% *MINAS CRUDES*.

17-C

mined by applying a proportionality constant, modified to account for the effect of more efficient equipment, effective control measures, and advanced operating techniques, to the results of loss measurements made on similar installations. $NO_2$ losses were computed on the basis of the relationship of $NO_2$ formed and unit of fuel consumed. $SO_2$ losses were based on the percentage of sulfur in the fuel burned.

Chemical Analysis of Major Hydrocarbons

The isolation of specific contaminant discharges allows the selection of undesirable pollutants from the gross air pollution. A separation into specific classifications of compounds, therefore, was made for gasoline vapor and automobile exhaust, Table IV.

The presence of ethylene and associated short-chain unsaturated hydrocarbons has been attributed by others to be the cause of orchid injury. These contaminants exist in both vaporized gasoline and automotive exhaust gases and are listed in Table IV under the heading, Olefins. The quantity of olefins in gasoline hydrocarbons is about 7 percent, which is subsequently increased to about 10 percent by automotive combustion.

## METEOROLOGICAL ASPECTS

General Meteorological Conditions

The Honolulu weather records clearly indicate that the prevailing winds for the area are relatively favorable in terms of an industrial location on Sand Island; however, two types of unfavorable conditions for dispersion of air pollutants from Sand Island occur with frequencies which will be indicated in the next section. Honolulu lies in the belt of easterly trade winds. The trade winds occur more frequently in late spring and summer and less frequently

# TABLE IV

## SUMMARY OF GASEOUS CONTAMINANT LOSSES
## TOTAL – HONOLULU AREA

| SOURCE OF LOSS | EMISSION – TONS / DAY | | | | | |
|---|---|---|---|---|---|---|
| | HYDRO CARBON | TOTAL | NITROGEN DIOXIDE | TOTAL | SULFUR DIOXIDE | TOTAL |
| **EXISTING SOURCES** | | 42.30 | | 26.00 | | 17.75 |
| PETROLEUM PRODUCT MARKETING | 14.00 | | — | | — | |
| INDUSTRIAL | — | | 20.35 | | 16.50 | |
| AUTOMOTIVE EXHAUST | 28.30 | | 5.65 | | 1.25 | |
| **PROPOSED SAND ISLAND REFINERY** | | 3.25 | | 1.35 | | 3.35 |
| STORAGE | 1.85 | | — | | — | |
| PROCESS | 1.40 | | 1.35 | | 3.35 | |

8-81

in January and February, but even in the winter months they are the predominant wind. This is strikingly demonstrated in the frequency of hourly wind directions at International Airport. During the 5-year period May 1950 through April 1955, winds from the northeast, east-northeast or east were observed 74 percent of the time; winds from the east-northeast alone were observed 41 per cent of the time.

In contrast, the next most frequent wind, northwest through north-northeast, occurred only 12 percent of the time. The frequency of occurrence of winds from this sector is opposite in phase to that of the trade winds, with higher frequency during the months December through March and lower frequency during the months June through August. The sea-breeze wind directions southeast through south-southwest occur with a total frequency of 8 percent, and their seasonal pattern, like that of the winds from the north, is opposite in phase to that of the trade winds. Hence, the winds already described account for 94 percent of the total, and of these, all but 8 percent would carry offshore the pollutants discharged from Sand Island.

Adverse Meteorological Conditions

The frequency of meteorological conditions in Honolulu associated with poor dispersion of air pollutants will now be considered. Mordy[5] has outlined the principal meteorological elements of interest. Jointly from local records of wind speed and of surface temperature inversions, he concludes that "the greatest air pollution hazard in terms of weather is during the months from November through February inclusive." He finds that 400-foot inversions of intensity 2°C or greater occur on 9.8 percent of the days during these months. He estimates the overall frequency of days of "smoky condi-

tions" at 15 to 20 days a year, and contrasts this with a frequency 10 times greater in Los Angeles.

Results of an alternative approach toward an estimate of less favorable conditions for dispersion of air pollutants are summarized in Table V. The record of wind at Honolulu International Airport during the same 5 years was examined for days on which light winds (less than 8 mph) from the sector northwest through northeast at 0100* or 0700 were followed by light winds from the south-southeast through west-northwest at 0700 or 1300. The air pollution significance of such shifts of light winds lies in the associated stability or temperature inversion preceding the shift, together with more or less indeterminacy of the wind direction before the new wind, predominantly a sea breeze, is established. Moreover, with winds from the south-southeast through west-northwest, the Honolulu area lies downwind of Sand Island.

Column "A" and row "A" of Table V indicate that the adverse conditions described above occurred 49 times during the 5-year period, or 10 times a year on the average. The distribution of cases by months is evidently in reasonable agreement with Mordy's designation of the period November through February as the months of "greatest pollution hazard." Analysis of the 49 cases reveals that the typical case is represented by winds from the northwest through north, 2-5 mph, at 0700, followed at 1300 by winds from the south-southeast through south-southwest, 5 mph or more.

Column "B" and row "B" of Table V indicate that if onshore wind speeds at 1300 up to 12 mph are included, these somewhat less adverse conditions occurred 197 times, or 39 times a year on the average.** The adverse condi-

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* 1:00 A.M. on 24-hour clock; 1300 is 1:00 P.M., etc.

** The essentially qualitative treatment employed in this section is sharply illustrated by the fourfold increase in frequency of "adverse" conditions when the definition is modified but slightly.

# TABLE V

## SUMMARY OF SPECTROGRAPHIC ANALYSES
## MAJOR HYDROCARBON SOURCES
## PERCENT OF TOTAL HYDROCARBON DISCHARGE

| TYPE HYDROCARBON | SOURCE | | |
|---|---|---|---|
| | GASOLINE | AUTOMOBILE EXHAUST | |
| | MIXTURE (WB 3-3) | CRUISING (S-37) | ACCELERATION, IDLE DECELERATION (S-39) |
| % NORMAL PARAFFINS | 38.14 | 35.31 | 36.15 |
| % BRANCH CHAIN PARAFFINS | 34.24 | 30.95 | 31.03 |
| % CYCLO PARAFFINS | 19.84 | 19.56 | 19.50 |
| % OLEFINS | 6.70 | 10.15 | 9.65 |
| % ACETYLENES | 0.72 | 1.84 | 2.03 |
| % AROMATICS | 0.36 | 2.19 | 1.64 |
| TOTALS | 100.00 | 100.00 | 100.00 |

DATA CONTAINED IN THIS TABLE IS BASED ON EXPERIMENTAL MATERIAL PERFORMED BY E. R. WEAVER. S. GUNTHER, AND THE LATE M. SHEPHERD OF THE NATIONAL BUREAU OF STANDARDS, UNDER THE AUSPICES OF THE LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT. SUMMARIES OF THIS WORK MAY BE FOUND IN:

(1) ANALYTICAL CHEMISTRY, 23, 1431 (1927)

(2) THIRD NATIONAL SYMPOSIUM ON AIR POLLUTION, APRIL, 1955

tions occurred in all months of the year, and for the period September through April at least twice a month, on the average.

Although high winds are generally associated with adequate dispersion of air pollutants, plumes from elevated sources may in high winds be brought near the surface "prematurely," i.e., before sufficient diffusion has occurred[10]. This phenomenon is essentially local: its adverse effects would be unlikely to occur beyond a few thousand feet from a stack 100-150 feet high.

The frequency of high winds from directions south-southeast through west-northwest, which would carry the refinery discharges to the nearby Honolulu shore, is indicated in Table VI. The 5-year record indicates that winds from this sector stronger than 18 mph occur on the average 48 times during a year, while winds stronger than 24 mph occur 11 times. Most frequent directions are south-southeast (22 and 6 times per year, respectively) and west-southwest (7 and 2 times per year, respectively). Although wind speeds greater than 18 mph were recorded in each month of the year, speeds over 24 mph occurred only in August and from November through April inclusive.

The two types of adverse meteorological conditions described in this section operate in essentially different ways. The high-speed effect described immediately above refers to elevated sources only, and when it occurs the proposed refinery discharges from elevated sources may be noticeable at the surface in a limited area some several thousand feet from the proposed refinery. Such instances can be expected at the Honolulu shoreline during about 50 hours each year.

# TABLE VI

FREQUENCY OF HOURLY WIND SPEEDS OVER GIVEN VALUE, FROM THE SECTOR SOUTH-SOUTHEAST THROUGH WEST-NORTHWEST

UPPER NUMBER: IN EXCESS OF 24 mph LOWER NUMBER: IN EXCESS OF 18 mph

HONOLULU INTERNATIONAL AIRPORT, MAY 1950 THROUGH APRIL 1955

| DIRECTION | MONTH | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | OCT | NOV | DEC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SSE | | 5 | 1 | 6 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 2 | 28 |
| | | 7 | 6 | 28 | 11 | 1 | 9 | 1 | 0 | 1 | 9 | 15 | 20 | 108 |
| S | | 0 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| | | 5 | 5 | 7 | 12 | 0 | 0 | 0 | 4 | 2 | 5 | 4 | 1 | 45 |
| SSW | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | | 4 | 1 | 2 | 1 | 0 | 0 | 0 | 4 | 1 | 1 | 0 | 1 | 15 |
| SW | | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| | | 3 | 3 | 4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 12 |
| WSW | | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 1 | 11 |
| | | 11 | 2 | 15 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 1 | 36 |
| W | | 3 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| | | 7 | 6 | 5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 20 |
| WNW | | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| TOTAL | | 8 | 4 | 19 | 2 | 0 | 0 | 0 | 7 | 0 | 0 | 12 | 3 | 55 |
| | | 38 | 24 | 63 | 24 | 1 | 9 | 1 | 17 | 4 | 15 | 21 | 23 | 240 |

B-12

In contrast to this, the low-speed meteorological condition described first is capable of affecting areas for distances of several miles, because of the slow rates of dispersion which are operative during periods of light winds. The morning period of uncertain wind movement attending the shift to a southerly direction will vary in duration from a fraction of an hour to 2 or 3 hours. Such instances may occur in the Honolulu area on 10 to 39 days during a year.

## DISCUSSION

The foregoing sections of this report have indicated that two effects of atmospheric pollution, pollution haze and orchid damage, occur in Honolulu during periods of adverse meteorological conditions. The problem posed by the addition of the proposed refinery source is concerned with the possible increase in intensity, frequency, and areal coverage of these effects, and with the possible development of additional manifestations of air pollution.

In analyzing the data herein presented, there may be a temptation to compare the estimated hydrocarbon losses from the proposed refinery (3.25 TPD) to the estimated hydrocarbon losses for the Honolulu area (42.3 TPD) and conclude that the net increase of hydrocarbon load is only 7.7 per cent. This procedure is invalid because the total existing emissions as shown in Table II are distributed over the entire Honolulu area of many square miles, whereas the contaminant discharges from the proposed refinery (Table III) will originate from a limited area. During approximately 86 percent of the time, the effluent from this latter limited area-source may be expected to blow to sea, and not affect the land mass. It is only during the remaining time that there is concern as to the effect of the refinery source on the quality of the air over the land mass. When the effluent from the refinery source moves over the land

mass during adverse meteorological conditions, its effect is primarily upon a limited-area sector downwind of the source, and therefore a proper appreciation of the percentage increase caused thereby must be based on its comparison with the effluents in and from this downwind sector.

A valid approach to the evaluation of the effect of the refinery discharge on the Honolulu area would be a computation based on the combined discharge of the two adjacent limited area-sources, i.e., the present industrial area-source and the proposed refinery area-source. It has been noted previously that the hydrocarbon discharge from the existing industrial area, the major contributor of pollutants to the downwind sector, is approximately 16 tons per day. Addition of the hydrocarbon discharge from the 24,000 barrels per day refinery, computed to be 3.25 tons per day, would produce an increase of 20 percent in the total hydrocarbon discharge to the downwind sector. Any future expansion of the refinery would result in a further increase in the impact on the atmosphere of the sector.

There are no available standards or criteria from which to predict the extent to which increases of this percentage within the downwind sector will intensify or enlarge the area of haze or plant damage, or result in other air pollution manifestations. It can, however, be concluded that any increase in pollutants discharged from the industrial limited area-sources will result in an increase of pollutional effects on the atmospheric environment of the area.

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## ACKNOWLEDGEMENT

Acknowledgement is made of the contribution of Mr. Richard S. Brief, Assistant Sanitary Engineer. He performed many of the engineering calculations in the air pollution portion of this report.

I.

APPENDIX A

DEPARTMENT OF HEALTH

Territory of Hawaii

Honolulu

Dr. Richard F. Boyd
Regional Medical Director
U. S. Public Health Service
441 Federal Building
San Francisco, California

September 16, 1955

Dear Dr. Boyd:

An oil refinery may be constructed on a portion of Sand Island off Honolulu by the Standard Oil Company of California in the near future. This may be a matter of some controversy as there is divided opinion in the city as to the desirability of this project. Many feel the refinery will contribute to the pollution of the city's air and will be a nuisance, particularly when the breeze comes from the sea. Others feel it will be an economic asset to the city. Honolulu Harbor, which lies between Sand Island and the city proper, is a source of bait fish for tuna fishermen. There is concern on the part of the tuna fishermen that the refinery may destroy the Harbor's fish resources.

The land on which the refinery is to be constructed belongs to the Territory and is under the control of the Territorial Commissioner of Public Lands. It is our understanding that, through the Commissioner, the oil company will enter into an agreement of sale with the Territory for the utilization of the site for a refinery. The agreement will provide for the approval of the plans and specifications for the refinery by the Commissioner of Public Lands, which function she will perform with the aid of advisors. The Board of Health will be the agency to advise on air and water pollution control and industrial hygiene measures. In addition to this control the oil company will have to secure a building permit from the Building Department of the City and County of Honolulu for the construction of the refinery. Territorial law requires the approval of the Board of Health before the City and County may issue a building permit. In this case our approval will require the inclusion of adequate control facilities.

The subject of waste control facilities for refineries is new to the territorial government. We would like to call on the U.S.Public Health Service for consultative advice, in recognition of the wealth of experience the Service has on this subject on a country-wide basis. We have conveyed this thought to the Land Commissioner who has expressed herself as being extremely receptive to it. She has asked us to explore the matter further with the intention of securing funds to defray any expenses which might be necessary to assure the provision of such consultative services by the Service to our Department.

The extent of the consultative services we would need is not clear to us at the present time as we have not been advised on the details of the proposed refinery. As a minimum we would like to secure the services of one of your air pollution control specialists, for example Dr. A. T. Rossano, here in Hawaii on at least three visits, before, during and after the construction of the plant. We probably should also have a visit by a specialist in water pollution control measures. Perhaps the Service might want to recommend additional experts as consultants not only from the Service but also from state or local government agencies with experience in the control of refinery wastes. Also, arrangements might be made for mainland meetings between refinery officials and Service experts.

The purpose of this letter is to determine whether consultative services can be made available to the Board of Health by the Service both on the mainland and in Hawaii and what would be required from the Territory in the way of financial assistance to secure such services. The Commissioner of Public Lands would like to have an estimate of the probable cost of such consultative services for budgetary purposes in connection with the development of the agreement of sale. We would appreciate an early reply as this matter is moving forward very rapidly.

Sincerely yours,

/s/ LEO BERNSTEIN, M.D.
Acting Executive Officer

III.

PHS, DHEW REGION IX, SAN FRANCISCO

To: Director, Robert A.Taft Sanitary Engineering Center
Attn: Chief, Air Pollution Control

Sept. 23, 1955

From: Regional Engineer

Subject: Request for consultative assistance on air and water pollution problems from the Territory of Hawaii

Enclosed is the subject request addressed to the Regional Medical Director by the Acting Executive Officer of the Territory of Hawaii Department of Health. This request presents a rather complete background on the assistance desired, which is detailed specifically in the first paragraph on page 2.

We need your advice and information on the service that the Center will be able to provide to the territory in order to answer this letter. There will undoubtedly be need for more than one individual to give proper consideration to this problem. We would normally be able to provide services in the field of water pollution through a staff member of the regional office. In this case, Mr. R. F. Poston would probably undertake to provide advice in this field. If this were the arrangement finally made, he would undoubtedly undertake this travel at Service expense.

In the air pollution control aspects of the proposal we are not staffed, as you know, to provide the services desired. If the Service can be of assistance, such assistance will have to be given by a staff member of SEC. Whether the three visits indicated (before, during, and after construction of the proposed refinery) can be financed by the Center, or whether some other arrangement will be necessary is a matter for your determination and we shall be guided by your conclusions in this regard in preparing an answer to the request.

It is suggested that this matter be discussed with your water supply and water pollution control people at the Center, also, because - while Mr. Poston is as well informed as any of the regional water supply and water pollution control engineers in industrial waste disposal problems - it is my feeling that Mr. Hayse Black, who has had a much more extensive contact and experience in this field, might provide more complete information to the territorial officials. Should Mr. Black be available to consult with the officials in Hawaii, we would have no objections to his handling this assignment.

Please let us have your response as promptly as possible, including an estimate of the probable cost to the territory for the consultative services the Center can provide. In a personal note

from Mr. B. J. McMorrow, Director, Division of Sanitation, he indicated that he hoped to have a reply to Dr. Bernstein's letter as promptly as possible, but certainly within ten days to two weeks. Accordingly, we should respond before the end of the month.

/s/ F. E. DeMartini
Sanitary Engineer Director

V.

DEPARTMENT OF HEALTH

Territory of Hawaii

Honolulu

September 28, 1955

Mr. F. E. DeMartini
Regional Engineer
U. S. Public Health Service
441 Federal Office Building
San Francisco, California

Dear Mr. DeMartini:

We have received information from representatives of Standard Oil of California on the nature of the refinery that is proposed for Sand Island, Honolulu, and on the amounts of various wastes that would be discharged during the operation of the refinery.

A brief description by the Company of the proposed refinery and control measures includes the following:

1. "A two-stage crude distillation unit of 25,000-barrel capacity in which crude oil is separated into elementary products for further processing. The equipment will include two fractionating columns, each with a fired heater, a rectifier column, and a sidecut stripper column. Auxiliary equipment is of a nature common to most refinery process plants and will include miscellaneous vessels, small tanks, heat exchangers, condensers, pumps, compressors, and interconnecting piping.

2. "A 10,000-barrel per day fluid catalytic cracking plant will be constructed for the production of motor and aviation gasoline components. Its principal equipment will include a fired feed heater, a reactor, a regenerator, and a product fractionation section consisting of six fractionating columns.

3. "A 1000-barrel per day alkylation plant for the production of aviation alkylate blend stock also will be constructed to produce aviation gasoline. The principal equipment will include reactors and fractionating equipment.

4. "A plant will be constructed for removal of hydrogen sulfide from the product vapors of the catalytic cracking plant and for conversion of this hydrogen sulfide into elemental sulfur.

5. "Flue gas from the fluid catalytic cracking plant which normally contains small traces of hydrocarbons and carbon dioxide will be completely incinerated so that it will contain only the usual products of combustion.

6. "A closed system will be provided so that hydrocarbon vapors which are released through safety valves will be contained for recompression and return to the refinery fuel system. In the event of an unusual emergency, the excess gas will be incinerated smokelessly.

7. "Electrostatic precipitators will be installed on the catalytic cracker to assure removal of essentially all dust from flue gases.

8. "Water from process units will flow through a series of American Petroleum Institute separators to remove oil and then to a colloidal air separator for final treatment to remove objectionable materials before release into the ocean. The volume of processed effluent will be approximately 1,500 gallons per minute.

9. "The refinery will produce civilian and miltary grades of motor gasoline, aviation gasoline, jet fuels, 50 cetane diesel, regular diesel, furnace oil, Navy special fuel, regular fuel oil and liquefied petroleum gas."

More specific data on air and water pollution as provided by the refinery officials are as follows:

1. "Estimated emission into the atmosphere:

| | | | |
|---|---|---|---|
| a. | Water vapor | - | 457,520 pounds per hour |
| b. | Carbon dioxide | - | 64,380 " " " |
| c. | Carbon monoxide | - | None |
| d. | Sulfur dioxide | - | 160 " " " |
| e. | Sulfur trioxide | - | 20 " " " |
| f. | Nitrogen oxides | - | 203 " " " |
| g. | Catalyst dust | - | 40 " " " |
| h. | Hydrocarbon | - | 142 " " " |
| i. | Ammonia | - | None |
| j. | Nitrogen | - | 281,690 " " " |
| k. | Oxygen | - | 14,620 " " " |

2. "The effluent water will contain:

| | | | |
|---|---|---|---|
| a. | Oil | - | 5 - 10 PPM |
| b. | Oxygen | - | 4 " |
| c. | Biological oxygen demand | - | 15 - 20 " |
| d. | Sodium chloride | - | 11,500 " |
| e. | Calcium chloride | - | 500 " |
| f. | Magnesium chloride | - | 500 " |
| g. | Sodium sulfate | - | 500 " |
| h. | Silicon dioxide | - | 40 " |
| i. | pH | - | 6.5 - 8.5 |

The "effluent water" will be discharged into the ocean off Sand Island. There will be no discharge of any wastes into Honolulu Harbor.

I would appreciate any comments you or your associates would care to make on this preliminary information. Particularly, I would like opinions on whether the estimated emissions for a plant of this size and type appear to be reasonable. The question of whether the amount of oil to be released in the liquid waste will be noticeable on the surface of the ocean interests us.

As Dr. Bernstein mentioned in his letter of September 16, 1955 to Dr. Boyd, our Commissioner of Public Lands will enter into an agreement of sale with the refinery company. There is some discussion at this time on whether the agreement should contain limiting values of air and water pollutants that the company would be required to observe during the operation of the refinery. We have been checking the air pollution control statutes of various states that we have in our file but cannot find that it is customary to set such values by law. However, we do not have at hand copies of the regulations of air pollution control districts in which such values would more likely be found. If you have such information at hand or could get it for us quickly, it would be very helpful to us. The value set by the Los Angeles air pollution control authorities would be of interest, particularly with comments on their usefulness.

I will keep you advised of developments on this matter. I hope we will receive an early reply to Dr. Bernstein's letter so that we may develop our plans for the utilization of Service consultants.

Sincerely,

/s/ B. J. McMorrow
Director, Division of Sanitation

BJMcM/lk

VIII.

To: Regional Director, Region 9, San Francisco, California. Attn: Regional Medical Director
For: Regional Engineer

Sept. 29, 1955

From: Director, Robert A.Taft Sanitary Engineering Center
Cincinnati 26, Ohio

Subject: Request for consultative assistance on air and water pollution problems from the Territory of Hawaii

Reference is made to your September 23, 1955 memorandum, same subject. We are pleased to offer the following comments and recommendations:

A. We urge that a realistic view be taken of this proposed petroleum refinery development. Heavy industry and resort areas are not necessarily incompatible, but the cost of waste control and treatment may prove exorbitant. Petroleum refinery wastes yield to treatment, but such wastes, for economic and practical reasons, cannot be returned to the original quality of the process water. We are dealing with processes involving mechanical equipment and the human element, both of which are subject to failure. In handling air contaminants and water pollutants, we would expect to design for high efficiency of control and treatment. However, we should recognize that irregularities in any industry are inevitable. The proximity of this proposed refinery site to fabulous Waikiki Beach is unfortunate. Undoubtedly other refinery locations on Oahu have been considered.

B. It is believed that the agreement between the Territorial Commissioner of Public Lands and the oil company should be rather specific in defining permissible limits for air and water contaminants. The cost of meeting rigid criteria may well influence the economics of plant location. In any event, it is imperative that an understanding be reached with the oil company as to effluent requirements prior to giving final approval.

C. If and when an agreement is reached between the Territory of Hawaii and the Standard Oil Company, it would be advisable to confer with company engineers or their consultants. The company has undoubtedly given consideration to both the air and water pollution problems of this proposed project. When authorized by officials of the Territory of Hawaii, the Sanitary Engineering Center Engineers could review such data as are available and determine what additional data are needed, with suggestions as to how such data could be obtained.

D. The program for study of the various problems created by this proposed industrial development should include:

(a) Reconnaissance of the area to determine the most suitable location with all phases of the problem considered. This survey should be made on the ground with access to local records. It is possible that reconnaissance reports prepared by the Standard Oil Company of California might be available for review.

(b) A study of the micro-meteorology and topography of the site and its environs and an assessment of the probability of occurrence of various types of insults to the Honolulu atmosphere and water. This might necessitate wind tunnel testing, and determination of ocean currents which would affect the local beaches.

(c) Decision of the maximum deterioration of the atmosphere and the water which should be acceptable.

(d) Establish with the oil company technical representatives reasonable and practicable criteria for maximum gaseous particulate and liquid effluent emissions from the refinery.

(e) Request reports, engineering drawings, and specifications for air and water, from the company which describe in detail control measures and waste treatment facilities designed to meet the criteria which have been established. These plans and specifications would be reviewed by Public Health Service specialists, and consultants if necessary, prior to initiating construction on this job.

(f) The air and water in the Honolulu area should be examined prior to operation of the plant in order to give a base line for comparison with plant performance. This work could be accomplished during the construction period, thereby offering opportunity to check conformance with design and specifications.

(g) Waste control and treatment facilities should be studied after the plant has been placed in full operation. This would include testing of the air in the Honolulu area and determination of the effect of liquid effluents on the receiving waters.

E. In the initial phase of this project, the Sanitary Engineering Center technical services could be accomplished through its regularly appropriated air and water pollution funds. Following this preliminary work, it will be possible to estimate the expenses involved by this project. Should it become evident that the expenses will exceed available Public Health Service funds, arrangements can be suggested to the Territory of Hawaii for supplying such fiscal assistance as necessary, possibly in the form of reimbursement for travel.

F. The Sanitary Engineering Center is prepared to undertake the initial consul-

tation as soon as requested. A schedule for subsequent work would have to be developed in cooperation with the Territory of Hawaii and the oil company in order to make personnel available when needed.

We desire to cooperate in every way possible with Dr.Bernstein and other officials of the Territory of Hawaii on this project. This memorandum outlines only the primary considerations. Conforming with arrangements made in a long distance telephone conversation October 3 between Messrs. Palange and DeMartini, Mr.Hayse H.Black will arrive in San Francisco Monday evening, October 17.

/s/ H. G. Hanson.

XI.

APPENDIX B

UNIVERSITY OF CALIFORNIA

Agricultural Experiment Station

Citrus Experiment Station
Department of Plant Pathology
Riverside, California

November 28, 1955

Mr. Arthur C. Stern
Robert A. Taft Sanitary Engineering Center
4676 Columbia Parkway
Cincinnati 26, Ohio

Dear Mr.Stern:

Enclosed you will find two copies of my report, "Observations on air pollution damage to orchids and other plants in the Territory of Hawaii, November 1955." As you will see from the report I have sent a third copy to Mr. F. E. DeMartini.

If I can assist you further or supply any additional information, particularly with regard carrying forward the recommendations, I should be pleased to do so.

It was a real pleasure to have participated in this program and I hope that I shall be able to serve you again.

Sincerely yours,

/s/ John T. Middleton, Chairman
Statewide Agricultural Air
Pollution Advisory Research Comm.

JTM:mg
Enclosures

P.S. If the Kodachrome slides supplied by Nekomoto are not required since Mr. Rose already has a duplicate set, I would appreciate their being returned to me for my use.

JTM

XII.

## Observations on air pollution damage to orchids and other plants in the Territory of Hawaii, November 1955

### SUMMARY

Observations were made for air pollution damage to plants in Honolulu and vicinity on November 8, 9 and 10, near Paia and Wailuka (Maui) November 10, and Hilo (Hawaii) November 11, 1955 with the assistance of B. J. McMorrow, Chief, and Robert Nekomoto of the Division of Sanitation, Territorial Board of Health.

Two types of flower damage were observed on orchid. The first is attributable to a gaseous effluent which causes the apical portion of the sepals to become dry, sunken and somewhat brittle. The toxicant responsible for this injury may be ethylene or associated short-chain unsaturated hydrocarbons. The second type of damage is apparently attributable to particulate deposits. In this case the materials affect principally the petals of the flowers and do not cause noticeable effects on the sepals.

Orchid dry sepal injury was observed only on Oahu in Honolulu and immediate vicinity. The extent of injury was most severe in the Kalihi section with considerable injury occurring in Kaimuki, less serious damage in Fosters Park, and only slight injury in Moanalua.

Injury to the petals attributable to particulate matter was predominant in the Kaimuki and Kalihi areas, but was of no significant economic importance. Serious damage attributable to particulate deposits was observed near Paia on the island of Maui. There was slight injury in the vicinity of Wailuka (Maui) and only slight particulate damage on Hilo (Hawaii).

The principal genera of orchids affected by dry sepal were Cattleya, Dendrobium and Phalaenopsis. No injury was observed on Vanda.

All growers contacted stated that dry sepal occurred coincident with the occurrence of Kona storms. A Kona storm was in progress during the course of these observations having begun on November 5.

Damage indistinguishable from dry sepal was stated to have been seen since the mid-1930's. Similar damage, but of economic importance, has been observed since the mid-1940's and has been increasing yearly both in area affected and extent of injury.

No visible injury to orchid foliage was observed.

Only limited observations were made on other types of vegetation, principally weeds and cultivated plants in the vicinity of the orchid production areas. In no instance were there any visible effects of oxidized hydrocarbons. No opportunity was provided to extend this type of observation nor to view plants susceptible to and grown in the vicinity of potential sulfur dioxide emitters.

Observations in T.H.

Economic damage to orchids, principally Cattleya, Dendrobium, and Phalaenopsis does occur in the vicinity of Honolulu. A damage present is that usually attributable to ethylene. There is no evidence for the presence of ozone or oxidized hydrocarbons.

## RECOMMENDATIONS

The areas affected by dry sepal should be better defined, both for the purpose of determining the extent of economic loss and to permit establishment of an adequate air sampling system which must be related to the occurrence of dry sepal on orchid.

Further observations should be made on orchids after more protracted periods of Kona weather, particularly on the island of Maui and possibly on Hawaii.

A survey should be initiated to determine the presence of other pollutants in the atmosphere as they may be indicated through their effects on native and cultivated vegetation.

A bio-assay system utilizing the response of plants to airborne pollutants should be established and appropriately bracket the Honolulu area. The requisite plants and appropriate systems for analysis are available and can be provided to those responsible for conduct of such a survey.

An air analysis system for the identification of ethylene in the atmosphere is currently being tested in the San Francisco Bay area. Pending the outcome of this program it may be appropriate to recommend the employment of such a system in Honolulu.

Since some of the biological services required for measuring the response of plants to pollution may be alien to staff members of the Territorial Board of Health, it may be appropriate to suggest that some phase of this work could be conducted cooperatively with staff at the University of Hawaii.

Provision should be made for the atmospheric measurement of oxidants possibly through potassium iodide and for hydrocarbons through IR spectra.

## OBSERVATIONS

Honolulu (Oahu), Kaimuki

Ing.--Cultural conditions moderately good. Stated that he has experienced dry sepal injury to Cattleya and Dendrobium but not to Vanda during the last 4 to 5 years. The occurrence of dry sepal is always coincident with Kona weather. Inspection of weeds normally susceptible to oxidized hydrocarbons, such as Solanum, Lactuca, and Euphorbia, failed to show the specific response of plants to these airborne toxicants.

Noa.--Discussions were held with Noa in his store. No opportunity

Observations in T.H.

was presented to view plants in the field with him, although some material on display showed typical dry sepal damage on Dendrobium. Noa stated that of the two production areas, Kaimuki is less likely to show severe orchid damage than is Kalihi.

Young.—Cultural conditions were only moderate to poor. There is considerable evidence of mechanical injury due to the production conditions of open lath and not much protective vegetation outside. Dry sepal was present on Cattleya and Dendrobium; there was also considerable mechanical injury to sepals and petals which could not be attributed to ethylene or related short-chain hydrocarbons. Young stated that fully opened Vanda flowers were damaged during the orchid show October 21-23, 1955. Several plants were shown, but the injury present was certainly atypical and is not caused by gaseous effluents such as ethylene. It is my opinion that this is a purely mechanical injury from cultural and handling operations.

Honolulu (Oahu), Fosters Park

Potter.—Dry sepal was first stated by Mr. Potter to have been observed in the mid-1930's and to have become important after the Second War. He stated that injury was worst on Dendrobium and Cattleya with no damage to Vanda. Observation of plants in the production houses in the park showed dry sepal injury occurring on Cattleya, Dendrobium and Phalaenopsis. There was no evidence of injury to Vanda. Potter stated that Strongylodon macrobotrys during Kona storms caused the flowers to drop but that there was no damage to leaves. So far as can be determined this is the only other plant mentioned that responds to Kona weather when orchid injury occurs.

Honolulu (Oahu), Rose Street

Uemetsu.—This place was visited because it was stated that carnations were grown. Carnations are known to respond to ethylene in the form of failure to open flowers normally. This disorder is sometimes called "sleepiness." The grower was aware of sleepiness in carnations, but was not clear whether sleepiness occurred in carnations grown at this place. The plants were in such poor cultural conditions that it was impossible to note many abnormalities. A large number of ornamentals were seen including chrysanthemum, China aster, zinnia, gladiolus as well as some vegetables including crucifers, none of which showed any evidence of response to ozone or oxidized hydrocarbons. The fact that there is no sleepiness in carnation here may mean that the plants are not growing adequately to respond, that levels of ethylene have not persisted long enough, or that concentrations are inadequate to cause damage to carnation but are sufficient to cause injury to orchid.

Honolulu (Oahu), Kalihi

Miyamoto.—Severe damage to Cattleya and Dendrobium was observed at this place. Miyamoto indicated that he had experienced dry sepal injury

Observations in T.H.

to orchide for all the 9 years that he had been in Kalihi and that it was becoming worse each year. He stated that the Cattleyas grown at Kalihi were affected 99% of the time when Kona weather persisted and that Cattleyas produced some distance away at Moanalua were usually affected only 1% of the time. Observations were made on weeds about the place, and there was no evidence for the presence of ozone or oxidized hydrocarbons.

Moanalua--Honolulu

Miyamoto.--No damage was seen to Cattleya except to a few plants that were in bud and exposed to the atmosphere in Kalihi before having been moved to Moanalua. There was slight damage to Phalaenopsis and no injury to Vanda. The fact that there was no damage to Cattleyas at Moanalua has considerable significance as it would show that with Kona weather and by removal from metropolitan Honolulu ethylene levels are sufficiently low to be nontoxic to orchids.

Honolulu (Oahu), Damon Estate

A brief stop was made here and it was seen that dry sepal was observed on a few white varities of Cattleya. There was no dry sepal present on Phalaenopsis.

Honolulu, University of Hawaii

Messrs. McMorrow and Nekomoto were kind enough to arrange a meeting with Beaumont, Nememoto and Shoji. Beaumont is executive secretary of the orchid growers group and had recently addressed himself to the governor in opposition to the establishment of the refinery in Honolulu. In discussion with Beaumont and Shoji it was brought out by them that injury to orchid was not limited to the Honolulu area, but had also been reported by an amateur grower on Molokai and had also occurred in a commercial production area in Hawaii. There were no specific details embracing these two reports. The exact limits of dry sepal injury in areal extent were not too well determined. There likewise was no information on the economic importance of dry sepal injury to the orchid industry. A very limited amount of work has shown that dry sepal of orchid could be reproduced by fumigation with ethylene. This is an experiment that has been conducted in many laboratories.

A single experiment was made using an unconventional system of collecting an air sample, passing it through a container enclosing an orchid plants, and determining the ethylene manometrically. It was stated that the orchid showed dried sepal and that there was ethylene present in the sample collected. The data were not made available and , as it was conducted by a graduate student as a preliminary single trial, no specific request for this data was made.

There can be little doubt that the personnel of the University of Hawaii is definitely interested in the dry sepal problem. Their interest

and talents dictate that they actively participate in a related phase of air pollution as it affects their industry needs. I discussed with them some of our systems for the use of plants as indicators for the presence of air pollution, and they evinced considerable interest. It occurs to me that here is an area that could be well bridged between the Territorial Board of Health and the University of Hawaii with assistance from our Air Pollution Research group at the University of California.

Shoji reiterated the information given by Potter regarding the occurrence of dry sepal in the mid-1930's and its growing importance after the Second World War. He made a further statement that its incidence was concurrent with commercial expansion in Hawaii and the general growth in business and industrial expansion. All of them agreed that dry sepal occurred coincident with Kona weather. The Kalihi area was alleged to be the worst. My observations would confirm Kalihi as most seriously affected of the districts seen.

Paia (Maui)

Takakura.--Experienced severe damage to Cattleya flowers due to recent weather conditions, strong winds, and a very heavy deposit of particulate matter. The black residue on the flowers certainly was responsible for poor quality. It probably contributed to the desiccation of the margins of the petals although not much damage occurred to the sepals. There was no evidence of dry sepal on Cattleya or Dendrobium. Some of the Dendrobiums showed dry sepal-like symptoms which could be easily confused with those attributable to ethylene, but no doubt this condition restricted in Dendrobiums is largely associated with the genetic make-up of the material. If the damage on Dendrobium were due to ethylene injury would have been observed on susceptible white Cattleyas.

Chee.--Fair growing conditions with severe mechanical injury. There is considerable evidence of a particulate deposit. No evidence of dry sepal on Cattleya or Dendrobium.

Wailuku (Maui)

Yamato.--A very good cultural condition obtained here. There was only slight evidence of mechanical injury and only a moderate amount of particulate deposit on the petals. There was no evidence of dry sepal although there was bud failure and petal discoloration on some Dendrobiums.

Hilo (Hawaii)

Bowman.--Cattleyas were grown outside. The foliage was rather chlorotic, but the plants very obviously sturdy. There is no evidence of dry sepal and very little mechanical injury despite the environment in which the plants were growing. Dendrobium and Phalaenopsis grown within lath and under cover

Observations in T.H.

did not show any symptoms of dry sepal. Mrs.Bowman reported that she did experience dry sepal last Easter following heavy trucking of sugar cane by diesel transport past her home.

Kono.--An extensive collection of Cattleyas was observed with no evidence of dry sepal or other types of injury. An unusually large and special collection of Vandas was present, none of which showed any injury.

Nakagawa.--No dry sepal was observed on Cattleya, Dendrobium, Phalaenopsis or Vanda. Nakagawa also stated that some lines of Dendrobium showed poor petal coloring and a tendency to wither readily.

Oda.--No evidence of dry sepal on Cattleya, Dendrobium, Phalaenopsis or Vanda, although rather extensive disfiguration of flowers was caused by widespread virus infection.

Tanaka.--Dry sepal was known to this grower from observations of the disorder in California and some of the eastern orchid production states. He had never seen dry sepal in any of the plants grown in Hilo. He did report that plants taken from Hilo to the orchid show in Honolulu last October showed dry sepal injury in Honolulu and on the flowers that developed from buds on plants exposed in Honolulu. Tanaka had rather a moderate particulate problem on flowers present. There was no evidence of dry sepal on Cattleyas seen.

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The damage to orchid flowers is one of the few tangible bits of evidence of the presence of noxious levels of pollution in Honolulu. Orchids, principally Cattleyas, Dendrobiums, and some Phalaenopsis, are especially sensitive to ethylene and related short-chain unsaturated hydrocarbons. In the States the dry sepal injury to orchid occurs throughout most of the year in the Los Angeles and San Francisco air drainage basins. The incidence of this disturbance is higher in the fall and winter months than in the summer months. Surveys to relate the incidence of dry sepal to oxidant level have not been adequately pursued. Air samplings to determine the relationship of dry sepal to measurable contaminants in the atmosphere have likewise not been pursued with much diligence. It would appear, based on the information available, that dry sepal does not materially increase as the oxidant level rises. There does appear to be some relationship between continued low level of inversion and the occurrence of dry sepal, the occurrence being largely one of dry sepal during quiet weather periods rather than periods with abnormally high oxidant level. With the data at hand there does not seem to be any obvious correlation between the occurrence of dry sepal and the occurrence of oxidized hydrocarbon injury on plants adjacent to damage to orchids. The field sampling program current in the San Francisco Bay area may throw some light on the occurrence of dry sepal and the presence of toxicants.

XVIII.

Observations in T. H.

It is certainly essential that air analyses be started in Honolulu to determine levels of ethylene and their principal sources. It is indeed significant that the dry sepal is so widely distributed in the area in the absence of any gasoline refinery system.

May I acknowledge here my sincere thanks to Dr. R. K. C. Lee, President, Territorial Board of Health, Mr. B. J. McMorrow, Chief, Division of Sanitation, Mr. Robert Nekomoto and Mr. Francis Woo for their every attention to my needs and their helpfulness in accumulating the above-reported information in such a short period of time. They are all keenly aware of the importance of air pollution and are surely eager to move forward on a constructive air pollution abatement program.

/s/ John T. Middleton

cc: Arthur Stern
F. E. DeMartini

November 28, 1955

Observations in T. H.

## ADDENDA

Legend for enclosed Kodachromes (slides secured through the courtesy of Mr. Robert Nekomoto).

5. Spray of Dendrobium showing flower failure and decoloring of petals associated with exposure to ethylene. Apical flowers are normal as the buds for these flowers were apparently not exposed to ethylene.

9. Close-up of flower from 5.

13. Dry sepal injury to a sepal of Cattleya. This sepal must have been affected some while ago and the extent of collapse attributable to secondary invasions since the concentration would appear to be low from the fact that the other two sepals show very little or no damage.

16. Typical effects of dry sepal on a white variety of Cattleya. Note the absence of damage to petals.

20. A single Cattleya flower which has been exposed to the effects of unsaturated hydrocarbons, but the principal effect is due to the secondary invasion or organisms. Petal damage is usually not associated with ethylene.

1 Editor's Note: Kodachromes to be furnished separately.